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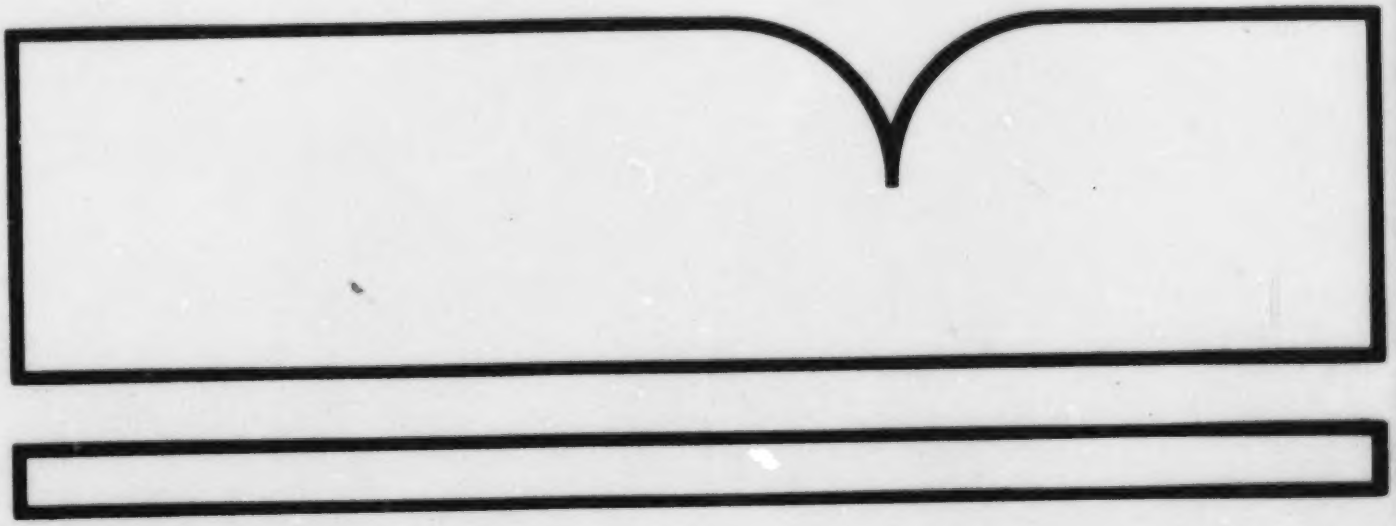

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16. ABSTRACT Surveys of lake water quality in northern Minnesota and Wisconsin reveal that approximately three-fourths of the lakes sampled are susceptible or potentially susceptible to acidification using the calcite saturation index as an approximate classification scheme. For some of the lakes in northern Wisconsin that fall above the upper curve, the threshold for acidification has already been exceeded. Historical data for 22 of the 127 Wisconsin lakes show large fluctuations of pH but as a group they show no obvious trend. For some of the low alkalinity lakes, the trend is in the direction of acidification; while for others, an increase in alkalinity appears to have occurred where there has been significant land use in the affected watershed. An indepth comparative study of these historical data is needed. Limited data are available to determine the significance of the present atmospheric loadings of acids. Acid loadings by precipitation can be directly related to the resulting effects on lake pH as a dose-response relationship. Verification of these relationships and their application to individual watersheds is one of the most important research needs. The importance of measuring pollutant components lies in determiing whether or not the chemically and biologically active forms and concentrations that make up the total dose are sufficiently comparable when interpreting cause-effect relationships. If comparable, the results pertaining to ecological responses observed in Scandinavia and elsewhere can be directly translated to predicting, understanding and controlling the developing ecological effects being observed in North America.

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1984

Susceptibility of aquatic and terrestrial resources of Minnesota, Wisconsin, and Michigan to impacts from acid precipitation: Informational requirements

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The resulting consequences of atmospheric pollution of the surface and ground water resources over most of the North America continent are just now being realized[1]. Regions sensitive to acid precipitation, based on bedrock geology around Lake Superior in the Minnesota-Wisconsin-Michigan-Ontario region are shown in Figure 1[1,2].

Surveys of lake water quality in northern Minnesota and Wisconsin, Figure 1, reveal that approximately three-fourths of the lakes sampled are susceptible or potentially susceptible to acidification using the calcite saturation index as an approximate classification scheme[3]. Most of the 103 lakes studied in northern Minnesota were above pH 6.0, Figure 2, a value found necessary for the successful natural propagation of most fish species[4-7]. However, more than 50 lakes of the 350 surveyed in northern Wisconsin were below pH 6.0. The total number of lakes in Wisconsin having a pH at or below 6.0 with little or no alkalinity is estimated to be 2,600. Many of these lakes are oligotrophic and are found in sandy quartzite soils. Some lakes are surrounded by or drain bog areas and are naturally acidic. Presently there are insufficient data to determine whether or not the shaded areas shown in Figure 1 predict with a high degree of confidence the lakes (watersheds) with low alkalinity (buffering capacity) and therefore high susceptibility to change from acid precipitation.

The relationship of pH and Ca in lakes has been suggested as a simple method to test for acidification,[8] Figure 3. Some of the lakes in northern Wisconsin fall above the upper curve, Figure 3, indicating that for the most dilute, lowest calcium concentrations, the threshold for acidification has already been exceeded. Historical data[9] for 22 of the 127 Wisconsin lakes plotted in Figure 3 show large fluctuations of pH but as a group they show no obvious trend. For some of the low alkalinity lakes, the trend is in the direction of acidification; while for others, an increase in alkalinity appears to have occurred where there has been significant land use in the affected watershed. An indepth comparative study of these historical data[9] is needed.

Limited data are available to determine the significance of the present atmospheric loadings of acids. The annual loading values of sulfate in kilograms per hectare for the northern Minnesota region range from 4 to 14 kilograms over a 7 year period with a mean of 11 kilograms[10]. The significance of this can be assessed in comparison with Scandinavian data,[11] Figure 4, if one assumes that the response characteristics of North American watersheds are similar. The "threshold" of acidification for the most sensitive systems is currently being exceeded in most of the eastern half of North America. Acid loadings by precipitation can be directly related to the resulting effects on lake pH as a dose-response relationship. Verification of these relationships and their application to individual watersheds is one of the most important research needs.

The chemical composition, species ratios, and changes in concentration of components in snow melt water are shown in Figure 5. The snow-season loading of components as determined by snow core composition from 65 different sites in northern Minnesota, Figure 1, are also given. These data for snow have similar features to those that were observed in Norway[12].

The importance of measuring pollutant components lies in determining whether or not the chemically and biologically active forms and concentrations that make up the total dose are sufficiently comparable when interpreting cause-

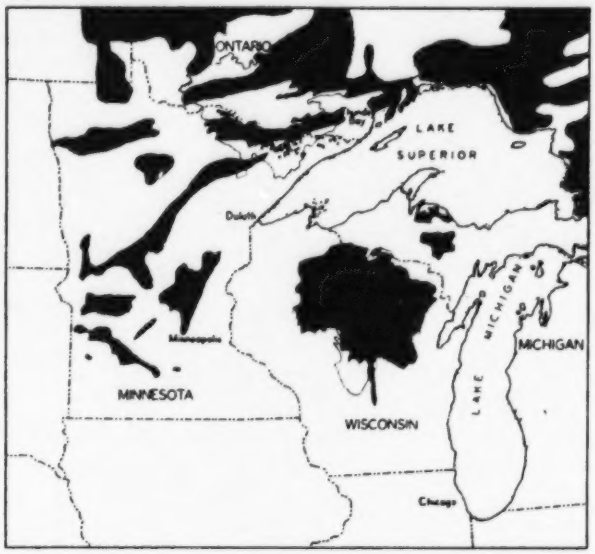

Figure 1. Study lakes (○, ●) in northern Minnesota and Wisconsin showing the relationship with areas (shaded) predicted to have high sensitivity to acid precipitation based on bedrock geology that may provide little or no buffering capacity[1].

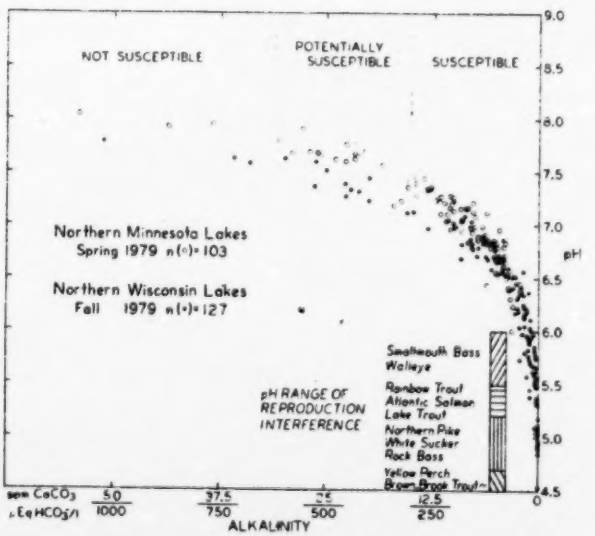

Figure 2. Relationship between pH and alkalinity in 103 northern Minnesota wilderness lakes and 127 northern Wisconsin lakes. The criteria for susceptibility are based on calcite saturation[3]. Fish species differences of reproductive interference are shown as approximate pH ranges[4-7].

effect relationships. If comparable, the results pertaining to ecological responses observed in Scandinavia and elsewhere can be directly translated to predicting, understanding and controlling the developing ecological effects being observed in North America.

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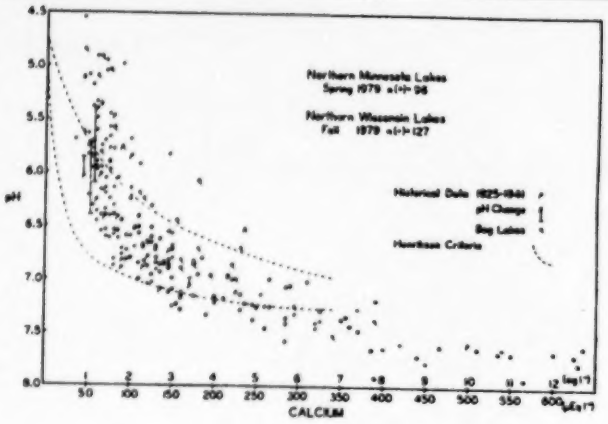

Figure 3. Calcium and pH values for 96 northern Minnesota lakes and 127 northern Wisconsin lakes, 1979, are shown in relationship to suggested criteria for determining acidification[8]. Examples of historical changes are shown. Lakes with highly colored water, bog lakes, and where historical data are available are noted.

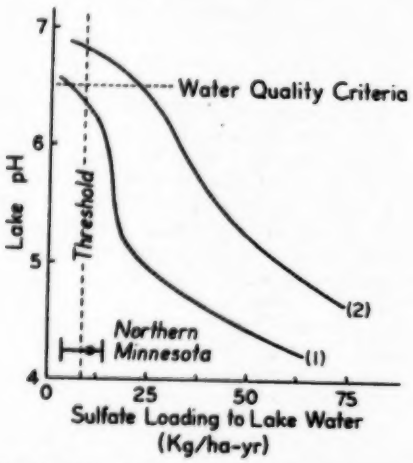

Figure 4. Relationship of lake pH to acid loading measured as sulfate for Swedish lakes in extremely sensitive surroundings, curve (1), and in somewhat less sensitive surroundings, curve (2), in relation to a threshold of lake acidification[11]. The sulfate load in northern Minnesota ranges from 4–14 kg/ha-yr with an average of 11 kg/ha-yr[10]. Water quality criteria are for the protection of both freshwater and marine aquatic life[12].

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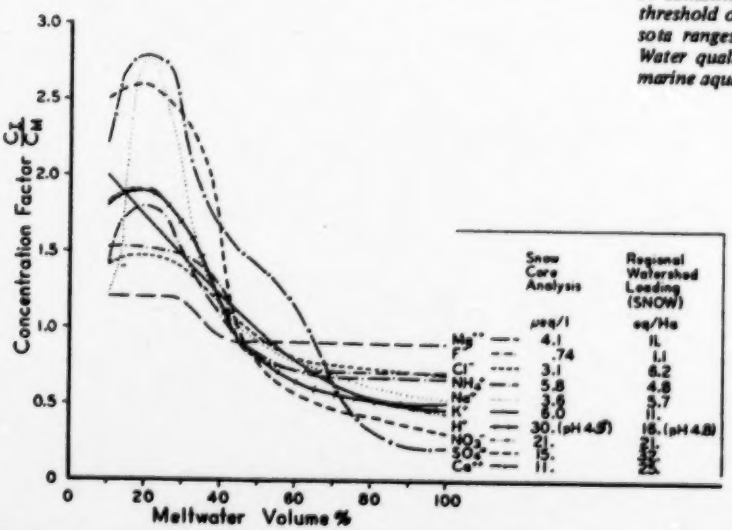

Figure 5. Snow melt chemistry and regional snow loading (1978) for northern Minnesota wilderness areas. Concentration factors for major ions in meltwater are given, C_I = concentration in the I-th fraction and C_M = average concentration of the sample. Snow loading values are computed from 36 sites[10].